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GOES R

A New Environmental Observing System for the 21st Century

Dave Jones

Introduction

This article describes a new geostationary environmental satellite observation system being planned by the National Oceanic and Atmospheric Administration (NOAA). GOES-R is in the planning stages to be the first in a series of the most advanced environmental observation satellites dedicated to supporting weather and water, ecosystems and coasts, climate and commerce. You can think of the "R" in GOES-R as increased Resolution in all of the sensors that will be on board. Planned for launch in 2012, GOES-R and will scan the Earth nearly five times faster than the current GOES satellites on orbit today. By the way, GOES is an anacronym for Geostationary Operational Environmental Satellites. The satellites will provide an increasing user community such as: television meteorologists, private weather companies, the aviation and agriculture communities, and national and international government agencies, with about one hundred times the amount of data currently provided.

A Nation in Danger

Today, some one hundred million Americans live along the nation's coasts, an area at high risk from natural disasters due to hurricanes, erosion, and flooding. Two-thirds of the country's population lives concentrated within urban areas, which are also vulnerable to the destructive forces of nature and statistics from the National Weather Service show the U.S. experiences more severe weather than any other country in the world. As urban and coastal populations rise, so too does America's vulnerability to severe weather and hazards related to air quality, water quality, atmospheric

Figure 1 *A large tornado cuts a path through Crawford County Sunday, May 4, 2003, east of Girard, Kansas. This storm was part of a large outbreak of severe weather that occurred during a 7-day period in May 2003. It is anticipated that GOES R will aid forecasters with the tools to provide advanced warnings of severe weather that will save lives and property. Image courtesy AP/Wide World Photos.*

dispersion of dangerous materials, and climatic variations. With the increased risks and costs, comes the need for improved and timelier weather forecasts, data, and storm warnings.

Emergency response plans require real-time decisions about evacuations affecting thousands of households in a single incident.

In May 2003 alone, the nation was besieged by more than 400 tornadoes over seven days in 19 states, killing 40 Americans and doing hundreds of millions of dollars in damage (see **Figure 1**). Later in the year forest fires raged across the West Coast, and Hurricane Isabel severely impacted the Mid-Atlantic region from the Carolinas through Virginia, Maryland, Pennsylvania, and well into Canada. In the two previous years nine tropical storms and one hurricane struck the U.S. causing 54 deaths and $6.3 billion in damage.

The losses described above would have been much worse if not for accurate and timely forecasts and warnings issued by the National Weather Service at the national, regional, and local levels.

As much as one-third of the U.S. economy—$3 trillion is influenced by climate, weather and natural hazards. In the agricultural businesses alone forecasting precipitation, drought, frost and seasonal climate variability determines optimal growing practices and may afford benefits of $100 million annually.

The energy sector is dependent on forecasts as well, to determine future regional demand for electricity, oil, and gas. Additionally, marine and air transport gain cost savings through routing to avoid weather risks and delays. Coastal recreation and tourism, one of the nation's largest economic drivers with an annual economic value of about $24 billion, is implicitly dependent on weather and marine forecasts.

A New Environmental Observing System for the 21st Century

In general, weather information provides market options that help industries protect themselves financially against adverse conditions. And in the military, weather information is regarded as a critical part of operations and a force multiplier. In order to have improved weather forecasts, the data gathering systems must also be improved. These remote sensing data gathering systems, on the ground, in the water, in the air, and in space provide the input to sophisticated numerical weather prediction models. From the standpoint of these models, good information in equals better information out.

The GOES System

The impressive imagery of cloud cover produced by the GOES series, as viewed from orbit high above the Earth, has become a highlight and staple of television weather forecasts. Forecasting the approach of severe storms for more than 25 years, GOES has remained an essential cornerstone of weather observations and forecasting.

Above the Equator, at an altitude of 36,000 km (22,300 miles) two GOES satellites continuously observe, measure, and report environmental conditions across the U.S., its coastal regions, and bordering oceans. Hovering at this altitude, GOES 10 and 12 are the current satellites in a geostationary orbit; this allows the satellites to remain constantly over a particular spot on the Earth's surface. One satellite is positioned over the U.S. East Coast (75 degrees West), another over the West Coast (135 degrees West), thus providing a view of almost all of North and South America and far out into the Atlantic and Pacific oceans where the jet streams transport weather systems around the globe (see **Figure 2**).

These satellites provide the best means to track hurricanes across the ocean to landfall, follow severe storm systems as they move across the U.S. or along the coasts, and monitor coastal conditions, forest fires, and atmospheric conditions such as turbulence or volcanic ash that affect air transportation. Additionally, GOES satellites monitor solar activity to provide warnings of severe solar storms that can significantly disrupt satellites, communications, aviation polar routes, and even power grids. Other nations—Europe, China, Japan, and India—also operate geostationary satellites at longitudes of national interest providing coverage around the globe.

Since 1974, the GOES program has brought large benefits to many sectors of the nation's economy while helping to protect the lives and properties of Americans. The present geostationary system is intended to serve through this decade.

By 2012, GOES-R, is expected to provide continuity and improved capability through the second and third decades of the 21st Century. The system is also

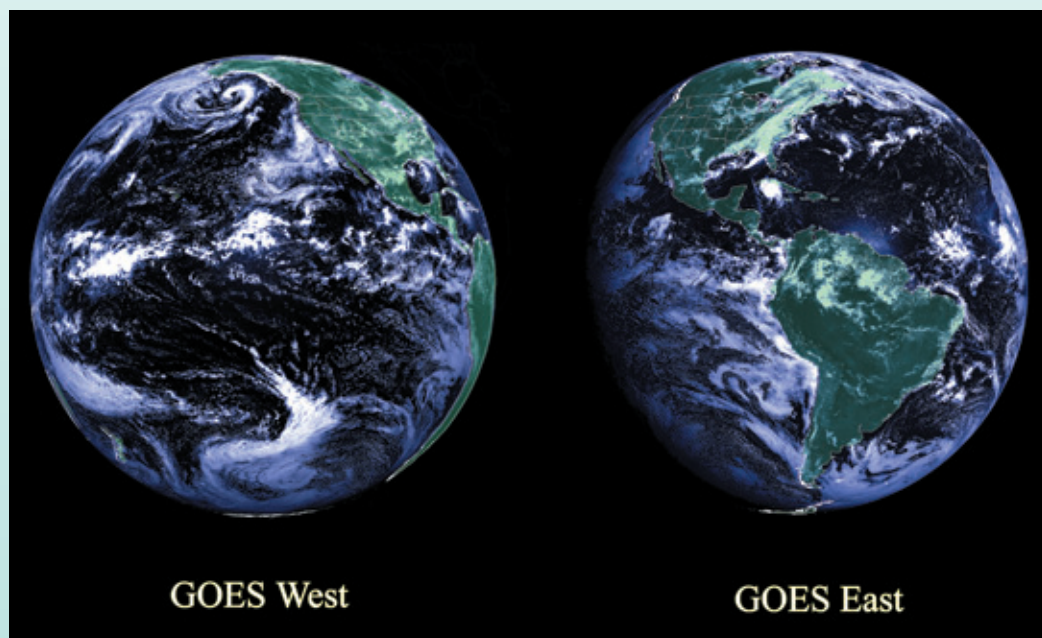

GOES West   GOES East

Figure 2 The two satellite views above represent the coverage areas of GOES East and GOES West. GOES East is situated above the equator at 75 degrees West and GOES West is situated above the equator at 135 degrees West longitude. These are the approximate views that will be seen from GOES-R. Some of the GOES East image is still dark in the Pacific Ocean. The image on the right shows Hurricane Charley on August 12, 2004 in the Caribbean Sea. Tropical Storm Bonnie is making landfall on the NW Florida panhandle with winds of near 45 mph while another tropical wave, soon to become Hurricane Danielle, makes its way off the African west coast. Image processed by StormCenter Communications, Inc.

planned to fulfill more demanding user requirements with advanced instruments and a 20-fold increase in vital data distributed to thousands of users.

To maximize the benefits from GOES-R, the National Oceanic and Atmospheric Administration (NOAA) is developing and integrating requirements and acquisition strategies for the instruments, spacecraft, ground system, and data products to ensure an end to end, seamless system architecture that reduces cost and risk.

Major new innovations in the spatial, temporal, and spectral resolution of data and image products are planned, including the capability to:

◆ View the whole Western Hemisphere every 15 minutes; currently we can see the Western Hemisphere every three hours;
◆ View the U.S. every five minutes; currently every 15 minutes;
◆ Provide targeted scans every minute simultaneously; currently cannot be done;
◆ Operate well calibrated instruments, suitable for climate monitoring; current limitations on GOES image navigation do not allow for significant climate monitoring;
◆ Provide imagery in 16 spectral channels at 0.5-2 km resolution (see **Figure 3**); currently 5 spectral bands;

◆ Provide high-resolution atmospheric soundings (more than 1,000 spectral channels) at 10 km resolution; not currently available;
◆ Provide lightning detection continuously over the hemisphere at 10 km resolution; currently not available from space;
◆ Provide enhanced space weather and solar information; currently done on a limited basis.

A Better "Eye" on Severe Weather

With more rapid information updates delivered to the National Weather Service, GOES-R will provide information leading to longer lead-times on warnings and advisories, thus saving lives, property, and reducing costs.

Dr. Louis Uccellini, Director of the National Centers for Environmental Prediction (NCEP) says, "...the key to the use of [GOES-R] data in rapidly changing situations like severe weather will not only be the improved data related to the high spectral instruments, but updating the view more frequently and to transmitting, receiving, and processing the data more rapidly...Every minute counts!"

When dealing with hurricanes every minute counts when forecasters work to determine the strength of these monster storms. As we enter a period of higher frequency hurricanes, which could continue through the next couple of decades, more rapid updates from GOES-R may significantly improve public warnings and advisories. Goldenberg and Landsea in 2001 concluded through research that "the present high level of hurricane activity is likely to persist for an additional 10 to 40 years. The shift in climate calls for a reevaluation of preparedness and mitigation strategies."

GOES-R Benefits

Major sectors of the U.S. economy will continue to remain vulnerable to severe weather. GOES-R, however, is expected to reduce the risks and provide enormous savings.

TRANSPORTATION

According to the Federal Aviation Administration (FAA) predictions, the

Hurricane Isabel rages across the Atlantic in September 2003.

total number of domestic passengers on U.S. air carriers is expected to increase from 604.1 million in 2000, and grow 3.6 percent per year to 927.4 million passengers in 2012. Weather is responsible for approximately two-thirds of air carrier delays, a cost of $4 billion, of which $1.7 billion is avoidable. The GOES-R advanced sounder will provide better predictions of thunderstorm development in broad regions of unstable air allowing better dispatch and routing decisions. Additionally, GOES-R will provide critical information that will lead to more accurate and timely warnings of volcanic ash plumes—a significant aviation hazard (see **Figure 4**).

COASTAL

Migration to and development of our coastal regions is expected to continue. More than one half of all Americans (53 percent or 148.3 million people) lived in a coastal county in 2000 (Census 2000 report, *Population Change and Distribution)*, thus being endangered by storms and other coastal hazards and stressing shoreline ecosystems. The ability of GOES-R instrumentation to image the Continental United States (CONUS) and to target specific storms at possibly up to 250-meter resolution simultaneously, combined with improved sea surface temperature and atmospheric sounding data will result in greatly improved hurricane intensity and landfall forecasts reducing risk and evacuation costs.

Figure 4 Ash rises from the crater of Mount Awu after a volcanic eruption, Thursday, June 10, 2004, in Tahuna, Indonesia. Ash plumes such as this cause serious aviation hazards around the globe as volcanoes erupt spewing millions of tons of ash and pollution into the atmosphere. GOES-R will help to detect these plumes more rapidly leading to increased aviation safety. Image courtesy: AP/Wide World Photos.

The GOES-R hyperspectral coastal water imager will provide the advanced capability to observe ocean color and ecosystem response as a function of tidal and storm conditions and supply data to monitor river plumes, red tides, and ecosystem health. Daily beach health reports derived in part by satellite may become a reality due to GOES-R.

AGRICULTURE AND ENERGY

The demand for seasonal to interannual climate and weather forecasts for the energy sector and agricultural planning continues to increase. GOES-R instruments will provide hourly, calibrated, high-resolution measurements of both short and long-term changes in the oceans, atmosphere, and cryosphere (those portions of the earth covered in ice). GOES-R will also provide soil moisture data, which is an essential precursor to drought and potential flood conditions. Working together with the National Polar Orbiting Environmental Satellite System (NPOESS), GOES-R will be the principal observing system for climate variability.
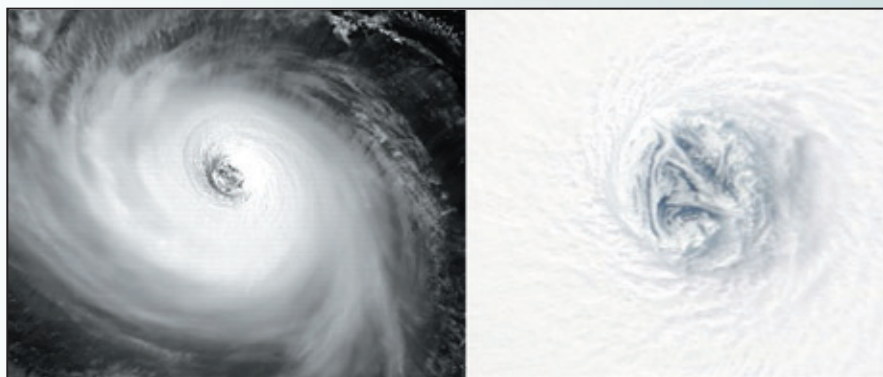

Figure 3 GOES-R temporal improvements will provide more capability to help with hurricane warnings. With the ability to image every five minutes routinely, hurricane eye wall dynamics will become evident and potentially aid researchers and forecasters to better understand rapid hurricane intensification and weakening. It may no longer be accurate to describe the center of a hurricane as "calm." Shown here is Hurricane Isabel in September 2003 as a category 5 storm. The image on the left is the current view from GOES while the image on the right is from NASA's MODIS sensor, which is a technology precursor to the GOES-R Advanced Baseline Imager (ABI).

Adverse weather creates additional cost on our highways and byways, at prices now averaging $78 billion a year in lost time and wasted fuel.

—Federal Coordinator for Meteorology

WEATHER AND WATER

The improved accuracy and resolution of GOES-R instruments and its associated advanced data processing and ground system is expected to improve weather analyses, warnings, and data delivery across the U.S. for severe storms, supply better data on precipitation and temperature, and more accurate tracking of lightning. GOES-R will provide the first ever operational lightning detection capability from space.

The GEO Lightning Mapper (GLM) is a sensor, capable of continuously mapping lightning discharges during both day and night, in a geostationary orbit. The GLM will provide information to identify growing, active, and potentially destructive thunderstorms over land as well as ocean areas. Two primary advantages of the proposed lightning mapper on GOES over ground based systems, is that it will be able to detect total lightning flash rate (cloud to cloud and cloud to ground) rather than just cloud to ground flashes, and it will be able to detect lightning over ocean rather than just over land.

SPACE WEATHER

The GOES space weather instruments monitor conditions on the sun (see **Figure 5**) and solar effects on the near-Earth space environment that includes the magnetosphere, ionosphere, thermosphere, and upper atmosphere (Holt and Liu, 2002). The solar observations can also be used to provide space weather forecasts for other regions of the solar system, such as the moon and Mars, where humans and technological systems may someday be vulnerable to space weather disturbances. Our Nation's reliance on the GOES space environment measurements continues to grow in importance to support a diverse user community, including industries and the general public dependent on electric utilities, radio communications, aircraft flights over polar regions, and navigation. 🌍

About the Author

Dave Jones is Founder, President and CEO of StormCenter Communications, Inc. He is also President of the Foundation for Earth Science and sits on the Executive Committee of the ESIP Federation (esipfed.org).

Figure 5 At 20 times the size of Earth, the largest sunspot observed since the November 2003 series of solar storms was pointed directly at Earth on July 23, 2004. Its unusually large size also means that it was visible to the naked eye (although you should never look at the Sun without a proper filter). Any time scientists see spots of this size concerns mount. If the active region generates coronal mass ejections (CMEs), massive explosions with a potential force of a billion megaton bomb, the possibility exists that large scale disruptions to satellites and power grids could occur.

ADVANCED BASELINE IMAGER (ABI)

Technically, GOES-R is planned to be a much more robust system essentially enabling forecasters, researchers, and many others to see the western hemisphere's ecosystems, coastal zones, weather, and water processes on a much higher frequency than ever before. GOES-R will carry an instrument called the Advanced Baseline Imager (ABI) which represents an exciting expansion in geostationary remote sensing capabilities. The ABI addresses the needs of the GOES user communities by increasing spatial resolution (to better depict a wider range of phenomena), by scanning faster (to improve temporal sampling and to scan additional regions) and by adding spectral bands (to enable new and improved products). Every product that is being produced from the current GOES Imager will be improved with data from the ABI (Schmit et al, 2004, Schmit et al, 2005). The ABI will improve the spatial resolution from nominally 4 km to 2 km for the infrared bands and 1 to 0.5 km for the $0.6\mu m$ band, 2 km for the $1.38\mu m$, and 1 km for the other visible/near-IR bands.

There will be a five-fold increase of the coverage rate. The ABI expands the spectral band number to 16; five bands are similar to the ones on the current GOES 10 and 12 imagers. The additional bands are:

◆ a visible band for aerosol detection and visibility estimation,

◆ a visible band for the detection of aerosols and vegetation;

◆ a near-infrared band to detect very thin cirrus clouds;

◆ a snow/cloud—discrimination band;

◆ a band will be used for particle size, vegetation and cloud properties/screening, hot spot detection, and moisture determinations;

◆ mid-tropospheric water vapor absorption bands to track atmospheric motions;

◆ a band to detect volcanic dust clouds containing sulfuric acid aerosol and cloud phase;

◆ a band for monitoring total column ozone;

◆ a band to derive low-level moisture and cloud particle size;

◆ a band useful for determining cloud top heights and effective cloud amounts.

The channel selection for the ABI is a balance of heritage with existing GOES bands (on the imager and sounder) and consistency with bands on other satellites (both in geostationary and polar-orbits).

ECONOMIC, SOCIAL AND FINANCIAL SECTORS GREATLY DEPEND ON ADVANCED INFORMATION — BETTER WEATHER PREDICTION OF IMPENDING DISASTERS FROM GOES-R WILL SAVE LIVES AND SAVE BILLIONS.

$380,000,000,000

The U.S. has sustained 58 weather-related disasters over the last 25 years with overall damages exceeding $1 billion for each event. 46 of the disasters occurred during or after 1990. Total cost of the 58 events was nearly $380 billion.

The National Oceanic and Atmospheric Administration (NOAA) is developing the next generation of Geostationary Operational Environmental Satellites (GOES) to monitor our Earth.

GOES-R

GOES-R spatial (how sharp the images are), spectral (number of instruments channels) and temporal (how fast the satellite scans the Earth) improvements will provide the information needed to manage the nation's resources to protect lives, property and the environment.

24/7/365

GOES-R will provide a continuous view of developing weather systems, with information every minute. High-intensity, short-lived events, like severe thunderstorms lasting only a few hours, can be identified in their early stages and forecast the area of maximum impact, expediting accurate warnings to the general public.

1,100 LIVES

Weather-related disasters have cost the U.S. nearly 1,100 lives and over $78 billion in losses over the past 5 years. Droughts and heat waves account for nearly two-thirds of the deaths and one-third of the damage costs in that time frame. Fires caused $7.8 billion in damages. Tropical storms, hurricanes and tornadoes caused nearly half the economic loss ($23.7 billion and 20% of the deaths).

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